APPENDIX E –

FLOODPROOFING GUIDELINES

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1.0 INTRODUCTION

The minimum standards for floodproofing are based on the Regulatory Flood elevation. The following table depicts the minimum elevations for various features and structures.

Opening into structures	Regulatory flood elevation +0.3m or wave uprush elevation (whichever is greater)
Basement Floor	Regulatory flood elevation -1.0m
Fill places around buildings and structures	Regulatory flood elevation
Electrical and Heating circuits	Regulatory flood elevation +0.3m or wave uprush elevation (whichever is greater)
1st floor (main) on raised buildings and structures	Regulatory flood elevation +0.3m or wave uprush elevation (whichever is greater)
Access roads, parking areas	Regulatory flood elevation -0.3m
Pedestrian Access	Regulatory flood elevation -0.8m

Floodproofing is defined as a combination of structural changes and/or adjustments incorporated into the basic design and/or construction or alteration of individual buildings, structures or properties subject to flooding so as to reduce or eliminate flood damages. It is acknowledged that this term is somewhat misleading, since total protection from flood damage cannot always be assured. However, if applied effectively, floodproofing can play a significant role in comprehensive flood plain management.

Floodproofing is generally most appropriate in situations where moderate flooding with low velocity and short duration is experienced and where traditional structural flood protection, such as dams and channels are not considered to be feasible. Although measures can be applied to both existing and new developments, it is usually impractical, expensive and extremely difficult to floodproof existing buildings.

Since floodproofing is best incorporated into the initial planning and design stages, new development has the greatest potential for permanent structural adjustment. In general, floodproofing can be applied most economically and effectively in the design of new buildings in developing areas. It can also be applied to infilling situations and proposed additions in developed areas. However, as well as providing adequate flood protection, new development within developed areas will have to take into account special considerations such as the aesthetic blend with neighbouring properties. Floodproofing, whether wet or dry should be no lower than the 1:100 year flood level. The only exceptions are in cases where an addition is proposed to an existing structure or there is one remaining infilling lot in a neighbourhood. In these instances, the floodproofing level should be no lower than the first floor levels of the existing structure or the adjacent structures.

2.0 TYPES OF FLOODPROOFING

All floodproofing measures can be described as active or passive and providing wet or dry protection.

2.1 ACTIVE VS PASSIVE

Active floodproofing requires some action, i.e. closing watertight doors or sandbagging for the measure to be effective. Advance flood warning is almost always required in order to make the flood protection operational.

Passive floodproofing measures are defined as those that are in place and do not require flood warning or any other action to put the flood protection into effect. These include construction of development at or above the flood standard, or the use of continuous berms or floodwalls

2.2 DRY VS WET PROTECTION

The object of dry floodproofing is to keep a development and its contents completely dry. Such can be carried out by elevating the development above the level of the flood standard or by designing walls to be watertight and installing watertight doors and seals to withstand the forces of flood waters. The benefit of elevated floodproofing is that it is passive and advance warning of an impending flood is not required. Temporary watertight closures, on the other hand, are considered to be active floodproofing usually requiring advance warning for operation.

Wet floodproofing is undertaken in expectation of possible flooding. Its use is generally limited to certain specific non-residential/non-habitable structures (e.g. arena, stadium, parking garage), but many of the techniques of wet floodproofing can be used with certain dry floodproofing approaches. The intent of wet floodproofing is to maintain structural integrity by avoiding external unbalanced forces from acting on buildings during and after a flood, to reduce flood damage to contents, and to reduce the cost of post flood clean up. As such, wet floodproofing requires that the interior space below the level of the flood standard remain unfinished, be non-habitable, and be free of service units and panels, thereby ensuring minimal damage. Also, this space must not be used for storage of immovable or hazardous materials that are buoyant, flammable, explosive or toxic. Furthermore, access ways into and from a wet floodproofed building must allow for safe pedestrian movement.

For new development, dry floodproofing above the level of the flood standard can generally be economically and easily achieved in the design and early construction phase. However, dry floodproofing of structures which will have portions below the level of the flood standard will require additional special design attention so that the structure will resist all loads including hydrostatic pressures.

3.0 TECHNICAL CONSIDERATIONS

Once flood waters enter a development, the risk of loss of life and flood damage will be determined by the location of the habitable portion of the buildings. The habitable portion of a structure is defined as living space intended for use by the occupant with the key concern being overnight occupancy. This includes buildings used for residential, commercial, recreational, and institutional purposes. In considering appropriate floodproofing measures, the habitable portion of the building should be designed to eliminate or minimize the risk of flood damage and loss of life.

As a rule, damages increase rapidly with the depth of flooding. Major structural damage occurs when a structure is weakened, totally collapses or is displaced. Damage to contents, such as finishes, trimwork, furniture, appliances, equipment and storage materials, also represents a substantial portion of the total loss. In addition, it is difficult to assign a dollar value to compensate for human suffering caused by a flood.

Thus, protection to at least the level of the flood standard is significant in reducing human suffering and property damage. In selecting between wet or dry flood protection, consideration must be given to the type of development, need for floodproofing and cost effectiveness.

Further, selection of active or passive measures will depend on location of the habitable portion of the development below or above the level of the flood standard, local flood warning, and access ways.

As well, all mechanical and electrical systems should be designed and installed so that the heating, lighting, ventilation, air conditioning and other systems are not vulnerable to flood damage during the flood standard. Where flooding could interrupt key power supplies, it may be necessary to provide stand-by or backup systems, with power and controls located above the level of the flood standard.

In order to determine the most appropriate floodproofing measure, the full extent of the flood hazard must be evaluated. This section outlines technical considerations which can assist in determining the most suitable floodproofing measure.

3.1 FLOODING AS A THREAT TO LIFE

Hazard to life is linked to the frequency of flooding, and to depth of flood waters and the velocity of flow in the floodplain. Depth increases buoyancy and velocity increases instability, so that each of depth and velocity should be studied independently or as a combined function.

a) Depth

Any person in the midst of a flooded area will be acted upon by a buoyant force equal to the weight of water displaced by that person. The volume of displaced water and this force increases with depth until neutral equilibrium is reached and the person begins to float.

Average adults and teenage children remain stable when standing in flood depths up to about 1.37 m (4.5 ft). The average school child 6 – 10 years old would float at about 1.1 m (3.5 ft), although smaller, younger children in this range would float at a depth of about 0.98 m (3.2 ft).

Hence, in terms of depth and individuals who could be present in the floodplain during a flood:

- depths in excess of about 0.98 m (3.2 ft) would be sufficient to float young school children;
- a depth of about 1.37 m (4.5 ft) is the threshold of stability for teenage children and most adults.

b) Velocity

Moving water in the floodplain exerts a lateral force resulting from momentum thrust of the flood flow. This force acts to displace objects in a downstream direction. The shear force of friction of a person on the wet surface of the floodplain resists this force. However, even relatively low velocities of flow in the floodplain can pose possible flood hazards.

The force exerted by various flow velocities can be developed for different age and size groups, but because its effect is tied to depth, a better appreciation of velocity effects can be gained by looking at both depth and velocity in combination.

c) Combination of Depth and Velocity

As a guide for personnel involved in stream flow/depth monitoring, the simple “3 x 3 rule” was developed in the U.S. based on 3 ft depth and 3 ft/s velocity values. The rule suggests that people would be at risk if the product (multiple) of the velocity and the depth exceeded 0.8 m2/s (9 ft2/s).

The Water Survey of Canada has the same rule of thumb and its Hydrometric Field Manual (1981) states, “a general rule of thumb which has been used in the past is arrived at through the product of the depth and velocity. Generally speaking, if the bed is firm and provides good footing, the product of these two factors should be slightly less than 1 m2/s, or roughly 9 ft2/s”.
It should be noted that this rule of thumb applies to trained professionals whose regular work accustoms them to the dynamic forces of river flows, buoyant forces from partial submergence and recognition of potential hazards, e.g. rocks, depressions, etc. They also enter the stream with equipment which will assist them in maintaining stability, e.g. tag line, wading rod, strap-on cleats for greater stability.

It is considered highly unlikely that such equipment would be available to most occupants of floodproofed buildings in the flood plain. It seems equally unlikely that these occupants would have the same level of experience as water survey staff in dealing with high depths, current speeds, unsteady footing, or cold weather/water conditions.

As a result, it is likely that the simple rule of 3 x 3 product (1 m2/s or 9 ft. 2/s) represents an upper limit for adult male occupants in the flood plain and that it would be reasonable to consider something lower as being more representative of a safe upper limit for most flood plain occupants.

As noted earlier, any person on foot during a flood may be subject to a number of forces in the floodplain. Excluding impact by ice and/or other debris, these forces include:

· an upward buoyant force, equal to the weight of the fluid displaced;

· a lateral force exerted by the moving water (linear momentum); and,

· unbalanced hydrostatic forces.

Resisting these forces are:

· the shear force of friction acting through the weight of the person standing on a wet surface in the floodplain.

Adults of average size would fall into the range between 976 -1952 kg/m2 (200 - 400 lb/ft2) but young children would more appropriately fall into a range of 732 - 1464 kg/m2 (150 - 300 lb/ft2). Only 7% of Ontario's population is within the 6 - 10 year age range, i.e. young children (Statistics Canada, 1981).

The coefficient of friction between foot apparel and wet grass, gravel, bare soils, pavements or other wet surfaces under flood conditions is not well known. A standard table of friction coefficients suggests that friction factors in the order of 0.3 to 0.6 could be characteristics of the ratio of the force to body weight required to initiate movement over unlubricated, dry surfaces. It is assumed that a lower friction factor range would be representative of the same state for a person standing on wet grass or pavement under flood conditions.

Any flood plain situation giving velocity and depth conditions lower than the appropriate curve for that individual is one where that person would be in a stable condition in the flood plain. Conditions of velocity or depth exceeding the appropriate stability curve would be unstable conditions for the same individual.

It is also appropriate to note that this analysis is based on a person standing still in the flood plain. Once a person begins to move to install floodproofing measures or leave the flood-prone area, stability is reduced further.

At low velocity but depths greater than 0.9 - 1.2 m (3 - 4 ft), most individuals would become buoyant. Similarly, in areas where flood plain depths may be less than 0.3 m (1 ft) but where velocities exceed 1.5 - 1.8 m/s (5 - 6 ft/s) encountered on roadways or bridge crossings, for example, stability conditions would be exceeded and some individuals would be swept off their feet.

Although no product rule exactly defines this region, a reasonable approximation of the low risk area can be made with a product rule that includes some constraints on the domain of depth and velocity. For example, a product depth and velocity less than or equal to 0.4 m2/s (4 ft2/s) defines the low risk area providing that depth does not exceed 0.8 m (2.6 ft) and that the velocity does not exceed 1.7 m/s (5.5 ft/s). By contrast, in a situation where the depth and velocity are 1.1 m (3.5 ft) and 0.3 m/s (1 ft/s) respectively, the product is less than 0.4 m2/s (4 ft2/s) but the depth limit is exceeded. Hence, these conditions define a high risk area for some individuals.

It is evident that this approximate classification is somewhat conservative; but until further research is undertaken, it provides a reasonable factor of safety for all individuals - young and old - who may be present in the floodplain.

3.2 DURATION OF FLOOD

The duration of a flood or the length of time a river overflows its banks, reaches its crest and recedes to within its banks depends on the efficiency of the river to transport the flood waters. Since the size of the watershed, time of concentration and duration of a flood affects the type of impact and pressure on the development, floodproofing measures must be designed to withstand these forces for the required period of time.

3.3 RATE OF RISE AND FALL

The rate of rise and fall of a flood to and from its crest can affect the type and extent of floodproofing. For example, where the rise and fall are very sudden, there may not be time to implement active floodproofing measures, such as watertight seals and doors and thus these approaches would be deemed unacceptable. The rate should also be considered in investigations of slope stability for certain types of soils where a quick drawdown of flood waters may pose problems.

3.4 FLOOD WARNING SYSTEM

The availability of advance warning can play an important role in determining the most appropriate measure. Where active floodproofing procedures are contemplated, lead time for implementation of appropriate protective measures and devices must be related to the amount of advance warning.

3.5 STRUCTURAL INTEGRITY

When buildings and structures are surrounded by flood waters, they cause unbalanced pressures and loadings on all wetted surfaces, which increase rapidly with depth. Unbalanced pressures can cause structural and sub-structural damages which can completely collapse or displace the development. In order to design the most appropriate floodproofing measures, it is important to determine the effect of stresses on the proposed building.

The stresses imposed on a building are due to hydrostatic, hydrodynamic and impact loadings, depending on its location. Hydrostatic loads are developed by water that is either still or moving at a low velocity. These loads may be defined as acting vertically downward (i.e., on floors), or vertically upward (i.e., uplift), or laterally when acting horizontally on walls. Hydrodynamic loads results from the flow of water against or around a structure at moderate or higher velocities. These loads are directly dependent on the velocity of flow, and can also adversely affect the floodproofing measures by causing erosion and scour. Impact loads are caused by water-borne objectives, debris and ice. Their effects become greater and more crucial as the velocity and weight of objects increase. Impact loads are difficult to predict and define accurately. However, a reasonable allowance can be made with the knowledge of the conditions of the site.

a) Superstructures (Above Ground)

<u>Hydrostatic Loading Effects</u>

Until the mid-1970s, it was assumed that standard design and construction practices - without modification - would be adequate to ensure that floodproofing by closures and seals could be conducted to moderate depth/ hydrostatic loading without threatening the structural integrity of the above ground/superstructure of most buildings. However, various research by the U.S. Corps of Engineers over the years, has suggested otherwise.

Studies on structures of conventional design have determined that:

- <u>brick veneer</u>, frame structures (such as a typical home) would resist hydrostatic loading up to about 0.8 m (2.5 ft) without damage;
- <u>concrete block</u> structures with limited or no reinforcement (such as the small warehouse building) displayed similar resistance characteristics and would not be damaged by hydrostatic loading up to 0.8 m (2.5 ft). Above this at 0.9 and 1.2 (3 and 4 ft) depths deflection and cracking became significant;
- <u>solid brick</u> structures responded in a similar manner. Tests with these also included end and side walls and walls with and without door openings. Walls

with ceiling joists (with and without door openings) were found adequate to resist loadings to about 0.8 m (2.5 ft). Walls with ceiling joists provide much stronger, but failed explosively when 2 x 4 supports were snapped; and,
- poured concrete walls were not tested, but from experience with other structural designs it was presumed that conventional design techniques would prove adequate against hydrostatic loads to at least 0.9 (3 ft).

Therefore, 0.8 m (2.5 ft) would appear to be the upper limit of effective flood depth (static plus equivalent hydrodynamic head) which can be resisted by conventionally designed structures without affecting structural integrity.

Studies on structural integrity during flow conditions have also given an appreciation of the permeability of conventional structures, in that:
- brick structures of conventional design begin to leak almost immediately and badly, when in contact with flood waters; and,
- concrete block structures of conventional design also leak badly at a rate that exceeds that of brick structures.

Tests also conducted to determine if materials or surface coatings would enhance water tightness found:
- no clear sealants (e.g. epoxy) were completely effective;
- no asphaltic material was completely effective;
- embedded roofing felts with polyethylene sheeting laid between a second brick course were found effective - but exceptionally stringent quality control of workmanship was required (particularly at joints);
- flood shields/bulkheads also presented difficulties and were for the most part ineffective unless designed especially with gaskets, smooth surfaces and locking bolts; and,
- certain thick, non-tear materials can be used as external “wrappings” to effectively seal buildings against infiltration. These are very special materials and fall into the category of “active” measures vs “passive”, permanent measures.

In summary then:
- conventional designs are not water resistant/waterproof for even low depths of flooding;

- new structures should be designed from scratch for complete water tightness (or if not completely watertight must incorporate an internal system to collect and remove water seepage); and,
- new structures using conventional designs can be made watertight (without re-design) but the only proven approach so far uses external “wrapping”.

Erosion

Flow velocities which will cause erosion of grass covered slopes or erosion around foundations are difficult to determine. Factors such as type of cover, slope and soil conditions must be taken into account. For most common situations, the range lies between 0.8 m/s and 1.2 m/s (2.5 ft/s and 4 ft/s) for easily eroded soils and 1.1 m/s to 1.5 m/s (3.5 ft/s to 5 ft/s) for more erosion resistant soils.

Impact Loading and Debris Accumulation

This aspect of structural integrity has not been studied in the field because it is practically impossible to establish velocity/depth limits associated with loadings caused by debris accumulation and the impact of floating objects on the flood plain. The nature of debris accumulations and size and shape of floatables simply varies too significantly.

Ice, debris and other floating materials can result in significant impact loading on buildings within the flood plain or increase the loads on buildings as a result of blockage. Although these loads are difficult to estimate a reasonable allowance must be made in design. Sites where the potential for such loading is high should simply be avoided or buildings should be designed/ landscaped to intercept/deflect materials before the building is affected.

In cases where floodproofing is achieved by elevation on columns or piles, the clearing space between the columns or piles should measure perpendicular to the general direction of flood flow and should be adequately designed to minimize possible debris blockage. The open space created below the level of the flood standard should remain essentially free of more buoyant or hazardous materials.

b) Substructures/Basements (Below Ground)

Based on normal (conventional) construction methods, any hydrostatic head in excess of 0.2 m (0.7 ft) may result in damage to basement floors (i.e. the upward force of groundwater on the basement floor).

Even where the basement of a single storey brick or masonry structure has been structurally reinforced and/or made watertight, structural integrity or buoyancy may pose problems when groundwater (saturated soil) levels are 1.2 - 1.5 m (4 - 5 ft) above the level of the basement floor. Much depends on the duration of the flooding, type of soil and the presence/effectiveness of the drainage system.

3.6 VEHICULAR ACCESS

Little or no information exists in the literature regarding ingress/egress criteria for vehicles. The question of safety for the passage of vehicles can be subdivided into:

- flood depth and velocity considerations affecting egress of private vehicles from floodproofed areas; and,
- flood depth and velocity affecting access of private and emergency vehicles to floodproofed areas.

a) Private Vehicles

In general, water contact is one critical issue in terms of its effect on the ignition/electrical system and the exhaust system. In the former, the distributor and/or spark plugs are the main items of concerns and those which are typical problem areas for most motorists.

Private vehicles come in all shapes and sizes and it is practically impossible to identify "typical" vehicles for assessing the elevation of key electrical components from the road surface. It appears likely that a depth of about 0.4 m - 0.6 m (1.5 - 2 ft) would be sufficient to reach the distributor or plugs of most private vehicles. They would fail to start at this depth and hence vehicular egress will be halted. Cars may start at lower depths but then "splash" from driving on wet pavement or from the radiator fan would become a concern.

The issue of the exhaust system and the effect that flooding can play on engine back pressures/expulsion of exhaust gases appears to be the controlling factor. Difficulty would probably be experienced in starting most vehicles if the vehicle is standing in water at a depth that covers the muffler. The vehicle may start and continue to run if it is quickly removed from the water but if remains at that depth, there is a strong possibility that it will fail soon after.

Again, it is practically impossible to generalize this depth but for most family automobiles something in the range of about 0.3 m - 0.4 m (1 - 1.5 ft) would be the maximum depth of flooding before potential egress problems would result.

A "typical" North American car would not be significantly affected by velocities up to about 4.5 m/s (15 ft/s) or more at flood depths at less than 0.3 m (1 ft). At running board depth or slightly above 0.3 m (1 ft) the maximum velocity for stability drops to about 3 m/s (10 ft/s) and at about 0.4 m (1.5 ft) depth an average vehicle may be displaced by velocities as low as 0.3 - 0.6 m/s (1 - 2 ft/s), with smaller vehicles becoming buoyant.

b) Emergency Vehicles

Emergency vehicles operate under the same constraints relating to the electrical/exhaust system. Most police vehicles and ambulances would be limited by exhaust considerations, although emergency vans are better equipped to avoid splash problems since the key electrical components are higher above the road surface.

Diesel fire vehicles with top exhausts appear best suited for flood conditions. Their road clearance is high and it is suggested that 0.9 m -1.2 m (3 - 4 ft) of flood depth would not present a problem. These vehicles are about 10 times heavier than most automobiles and hence are resistant to displacement by higher velocity flood flows. Operations at velocities in excess of 4.5 m (15 ft/s) would probably not pose a problem when these vehicles are moving over a good/non-eroding base.

3.7 PORTABLE OR MOBILE BUILDINGS AND STRUCTURES

A portable or mobile building is one that is not permanently tied or anchored to a foundation and can be transported by means of a hauler. Portable or mobile buildings can be located on individual sites or in a park or subdivision. They can be used for temporary purposes, such as for construction crews or as full-time residences/seasonal homes with overnight occupancy.

When located in flood plains, portable or mobile buildings are highly susceptible to flood damage. Since they are not affixed to a permanent foundation, flood waters may easily sweep such buildings off their sites. Without advance warning, residents can be entrapped in the building. In addition, portable or mobile buildings can increase the flood hazard as they collide with other structures or block bridge openings or culverts. Despite this, portable or mobile buildings often are located in flood plains because:

- flood plain land acquisition costs may be lower;
- swamp conditions and higher water table which prevail in flood plain areas may preclude construction of permanent homes with basements; and/or,
- potential recreational access by locating close to the water’s edge.

Ideally, portable or mobile buildings should not be located in the flood plain. However, when located in the flood fringe, they should be properly floodproofed to the flood standard, in order to prevent flotation, collapse and lateral movement. Due to the inherent hazard of remaining in a mobile building during a flood, contingency plans indicating escape routes and alternative vehicular access ways should be prepared.
Where the portable or mobile building is on site temporarily, it may not be feasible to meet all the requirements for floodproofing. In such cases, temporary location of portable and mobile buildings in the flood fringe may be considered where the time frame is very short and sufficient flood warning would allow the structure to be hauled away in advance of the flood.

3.8 FLOODPROOFING COMPLEXITY

The complexity of floodproofing techniques (and to a degree the cost) is best related to depth and type of floodproofing considered.

a) Closures and Seals

It appears that external walls can be floodproofed by closures and seals to a flood depth of about 0.8 m (2.5 ft). Beyond this depth, structural integrity is threatened and special reinforcing or revised designs (with poured concrete walls for example) are required.

Dry floodproofing to this depth can be completed with the use of impervious external "wrappings". These contingency wrappings are anchored beneath the ground surface along the foundation and rolled upward and hung into place along the walls of building prior to flooding. Equivalent dry floodproofing using internal sealants, doubled walls, etc. with flood shields at openings is more complex, expensive and uncertain as to effectiveness.

Basements can be closed and sealed to levels of about 1.2 - 1.5 m (4 - 5 ft) above the floor slab with poured concrete designs employing additional reinforcement and special attention to monolithic construction. Beyond this level, the procedure becomes complicated as buoyancy/uplift must be addressed through anchors and/or added wall and slab thickness.

Overall, closures and seals is fraught with possible problems and is considerably more complicated than other floodproofing approaches.

b) Elevated structures

Structures on Fill Floodproofing on fill is generally considered for slab on grade construction. It is not a complex procedure and conventional building techniques are employed once the pad is down. The principal concern is fill compaction which must usually be done in 0.2 - 0.3 m (0.5 - 1 ft) lifts. Beyond 0.6 - 0.9 m (2 - 3 ft). however, pad sizes increase, compaction requirements become more important and an engineer or soils consultant should be employed for design review and inspection. Increased elevation may also lead to requirements for pad sizes in excess of lot size and, hence, additional requirements for erosion protection, etc.

Houses with conventional basements can also be placed in fill to elevate the first floor to a level about 2.1 - 2.4 m (7 - 8 ft) above grade (i.e. the basement is founded on grade and the basement walls are surrounded by fill). At 1.2 - 1.5 m (4 - 5 ft) above grade, the procedure is complicated by the need for wall and slab reinforcement, and anchors to prevent buoyancy.

Elevation on Columns, Piles, Piers and Extended Foundation Walls
Elevated structures using these techniques must be designed with consideration for debris loading, orientation of supports, effective submergence on foundation soil conditions and anchorage, bracing and connection details, availability of mechanical equipment, etc. In most instances, an engineer should be consulted to ensure that the possible effects of flooding are considered in the design. There are more factors to consider than conventional house construction on fill and, hence, these approaches could be considered more complex.

The majority of elevated buildings use posts for support (steel or timber). Installation becomes more complex at lengths in the range of 3.6 - 4.8 m (12 - 16 ft) since machinery is needed for installation. A range of 3 - 3.6 m (10 - 12 ft) seems typical for most homes which use extended posts.

Mechanically-driven piles are reported to be the best solution if severe erosion is anticipated. Pile driving equipment and skilled operators are at a premium and, because of the initial expense, this technique may be too complex/unnecessary for flood depths less than 1.5 - 1.8 m (5 - 6 ft).

Piers/columns are generally constructed with brick, concrete block or poured concrete. The common elevation range for each of these approaches is as follows, beyond which increasing complexity is assumed:

- 0.4 - 1.8 m (1.5 - 6 ft) for brick piers;
- 0.4 - 2.4 m 91.5 - 8 ft) for reinforced concrete masonry piers; and,
- 0.4 - 3.6 m (1.5 - 12 ft) (or more) for poured in place, reinforced concrete piers.

Extended foundation walls make a relatively simple and effective foundation for elevated structures but again must be designed with consideration for loads and pressures anticipated in the flood plain.

Berms and Floodwalls

Berms (or levees) and floodwalls used for floodproofing are low structures built around single homes or individual industrial complexes. Property design is more complex since material and construction practices must be closely monitored, they must be regularly maintained (in the case of berms), and they usually require adequate pumping facilities to handle interior drainage and seepage. Both berms and floodwalls usually have some opening for access and consideration must be given to closure.

In many instances, berms and floodwalls should be designed by qualified professional engineers.

Intentionally Flooding a Building (Wet Floodproofing)

Intentionally flooding a building for the purpose of balancing internal and external pressures so as to maintain structural integrity is in itself not complex. To ensure minimal damage and quick clean up, a number of conditions have been placed on the use of wet floodproofing by agencies such as Canada Mortgage and Housing Corporation. Requirements include:

- at least two open able windows located on opposite sides of the building;
- tops of window sills to be not less than 150 mm below grade (to allow flood water into the basement);
- basements to remain unfurnished and contain nonhabitable space only;
- mechanical and electrical equipment, heating units and duct work to be located above the flood standard; and,
- sump pump required.

While wet floodproofing may be designed and provided for in a building, there is no guarantee over time that the requirements will be maintained. In particular, it is difficult to control the “finishing off” of basements which would then result in damages when wet floodproofing measures were put into effect. Therefore, while wet floodproofing may appear desirable initially, the ability to ensure the principles and requirements of wet floodproofing are maintained in the future must also be considered.

Above taken from Appendix 6: Floodproofing of *Technical Guide – River & Stream Systems: Flooding Hazard Limit* (MNRF, 2002).